JPPIPA 12(5) (2026)

Jurnal Penelitian Pendidikan IPA

http://jppipa.unram.ac.id/index.php/jppipa/index

Development of Desmos-Assisted Electronic Student Worksheet Based on the 5E Inquiry Learning Model to Enhance Mathematical Reasoning Skills: Supporting SDG 4 Quality Education

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Received: February 23, 2026
Revised: April 04, 2026
Accepted: June 06, 2026
Published: June 06, 2026

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DOI: 10.29303/jppipa.v12i5.15071

Abstract: This study aimed to develop an electronic student worksheet (e-LKPD) based on the 5E Inquiry Learning model assisted by Desmos and to evaluate its validity, practicality, and effectiveness in enhancing *mathematical reasoning skills (MRS)* in senior high school mathematics. A Research and Development (R&D) approach using the ADDIE model was employed, implemented through a one-group pretest-posttest pre-experimental design. The e-LKPD was developed for Grade X students at SMAN 1 Pariaman on the topic of Linear Programming. Expert validation yielded an average score of 98% (highly valid) across content, language, and media aspects. Practicality testing yielded teacher response of 88.6% and student response of 97% (both highly practical). Effectiveness was evaluated via N-Gain analysis; mean pretest scores increased from 32 to 71 post-intervention, with an average N-Gain of 0.57 (medium category). The Wilcoxon signed-rank test confirmed statistically significant improvement ($p \leq 0.001$). These findings indicate that the e-LKPD integrating the 5E inquiry model with Desmos technology constitutes a valid, practical, and moderately effective instructional tool for advancing mathematical reasoning skills in senior high school mathematics.

Keywords: Desmos; E-LKPD; Inquiry Learning 5E; Linear Programming; Mathematical Reasoning Skills

Introduction

The quality of learning is strongly influenced by teachers' ability to create interactive, meaningful, and student-centered learning environments that encourage active participation and critical thinking, as emphasized in Indonesia's current curriculum policy under Permendikbudristek No. 12 Tahun 2024. In mathematics education, teachers are expected to function not merely as transmitters of knowledge, but as facilitators who guide students to construct understanding through exploration, investigation, and reasoning activities. Effective instructional design therefore plays an important role in supporting students' conceptual understanding and learning achievement (Darmansyah, 2020).

Mathematics learning in the Kurikulum Merdeka emphasizes numeracy, mathematical reasoning, problem solving, and the application of mathematical concepts in contextual situations. However, mathematics instruction at the senior high school level still faces several challenges, particularly in developing students' mathematical reasoning abilities. One major issue is the limited integration of cognitive technology that supports conceptual exploration and dynamic visualization. In many classrooms, mathematics learning remains dominated by conventional lecture-based instruction and procedural exercises, causing

How to Cite:
Rahmi, Zen, Z., Jasrial, & Rayendra. (2026). Development of Desmos-Assisted Electronic Student Worksheet Based on the 5E Inquiry Learning Model to Enhance Mathematical Reasoning Skills: Supporting SDG 4 Quality Education. *Jurnal Penelitian Pendidikan IPA*, *12*(5), 676–684. https://doi.org/10.29303/jppipa.v12i5.15071

students to focus more on memorizing formulas than understanding relationships among concepts. As a result, abstract mathematical topics are often perceived as difficult and less meaningful for students (Puriasih & Rati, 2022).

This condition is reflected in the 2025 Education Report of SMAN 1 Pariaman, which showed a 15.42% decline in students' numeracy achievement compared to the previous year. The decrease occurred across all mathematics domains, including Algebra, Geometry, and Data and Uncertainty, as well as across cognitive levels of knowing, applying, and reasoning. These findings indicate that students still experience difficulties in mathematical reasoning, interpreting contextual problems, and applying concepts in problem-solving situations. Classroom observations conducted during the second semester of the 2024/2025 academic year further revealed that technology utilization in mathematics learning was still limited to evaluation activities through applications such as Quizizz, while interactive mathematical tools capable of supporting conceptual understanding had not been optimally implemented (Ardiansah & Zulfiani, 2023).

One mathematics topic that particularly requires conceptual visualization and reasoning ability is Linear Programming. This topic involves systems of linear inequalities, feasible regions, objective functions, and optimization processes that require students to interpret mathematical models both algebraically and graphically. Students often experience difficulties in visualizing solution regions and understanding the relationship between algebraic representations and graphical forms. Therefore, instructional media capable of providing dynamic visualization and interactive exploration are needed to facilitate deeper conceptual understanding.

Student worksheets (LKPD) are important instructional materials that can guide students through structured learning activities. However, conventional printed worksheets are generally limited in interactivity and do not adequately support exploration-based learning. The development of electronic student worksheets (e-LKPD) integrated with interactive digital technology offers a more adaptive alternative for mathematics learning. According to Ristiani & Hermita (2022), e-LKPD supports active learning through interactive features, immediate feedback, and flexible learning access. In this context, the integration of the Inquiry Learning 5E model (*Engage, Explore, Explain, Elaborate,* and *Evaluate*) is considered appropriate because it encourages students to construct mathematical concepts through systematic investigation and reasoning processes. The model also aligns with the principles of the Kurikulum Merdeka, which emphasize active, meaningful, and student-centered learning.

To support inquiry-based mathematics learning, this study integrates the Desmos Graphing Calculator as a cognitive technology tool that enables students to visualize graphs dynamically, manipulate parameters directly, and investigate mathematical patterns interactively. Through these activities, students are encouraged to develop mathematical reasoning and mathematical investigation skills, particularly in analyzing relationships among variables and interpreting graphical representations. Previous studies have shown that Desmos-assisted learning can improve students' conceptual understanding, engagement, and mathematical reasoning more effectively than conventional instruction (Novitasari et al., 2022).

The novelty of this study lies in the integration of three components within a single instructional product: the Inquiry Learning 5E model, Desmos-assisted dynamic visualization, and digital e-LKPD specifically designed for Linear Programming in senior high school mathematics learning. Unlike previous studies that focused separately on inquiry learning, Desmos utilization, or digital worksheets, this study combines these components to support students' mathematical reasoning abilities in accordance with the numeracy-oriented goals of the *Kurikulum Merdeka*. Therefore, this research aims to develop a Desmos-assisted Inquiry Learning (5E) e-LKPD and examine its validity, practicality, and effectiveness in improving students' mathematical reasoning abilities in mathematics learning.

Method

This study employed a Research and Development (R&D) approach, defined by Sugiyono (2019) as a systematic method for producing specific products and evaluating their effectiveness. The product developed is an e-LKPD based on the 5E Inquiry Learning model assisted by Desmos, designed to enhance students' mathematical reasoning skills (MRS) in the topic of Linear Programming. The development model adopted is the ADDIE model (Analyze, Design, Develop, Implement, Evaluate) following the framework refined by Branch (2009), selected for its structured sequential phases, iterative evaluation, and reliability in producing instructionally sound products. Effectiveness was examined through a one-group pretest-posttest pre-experimental design, in which the same group of students was assessed before and after the intervention without a control group. The ADDIE model was selected for its structured sequential phases, where each stage involves evaluation and revision, ensuring valid and reliable outcomes (Haviz, 2018).

Analyze

The analysis phase encompassed four components: (1) student analysis, (2) curriculum analysis, (3) concept analysis, and (4) product needs analysis. Student analysis identified Grade X students at SMAN 1 Pariaman as exhibiting heterogeneous learning styles kinesthetic (33.3%) and auditory (30.6%) being most prevalent. Diagnostic assessments revealed that 55.5% of students required special numeracy intervention, indicating difficulties in contextual problem interpretation, data analysis, and mathematical application. Curriculum analysis confirmed alignment with the Merdeka Curriculum learning achievements (Phase E) for Linear Programming (Systems of Linear Inequalities in Two Variables). The analysis concludes that conventional instruction lacks the interactivity and visualization capacity to address students' mathematical reasoning deficits.

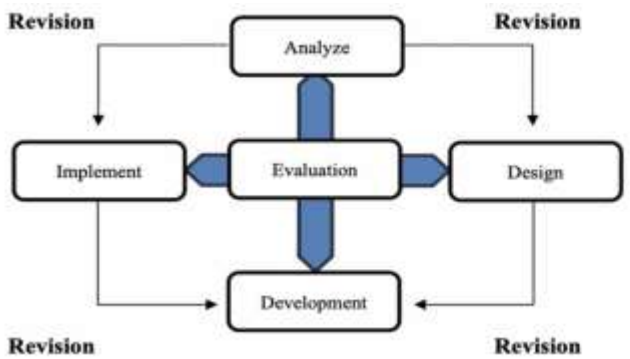

Figure 1. ADDIE model

Design

The design phase mapped each 5E stage to specific mathematical reasoning skill (MRS) indicators. The Engage phase was designed to activate mathematical observation skills; Explore to develop pattern recognition and data interpretation; Explain to strengthen conjecture formulation; Elaborate to enhance application and logical verification; and Evaluate to consolidate evidence-based conclusion drawing. Desmos activities were embedded within each phase to enable dynamic visualization. The e-LKPD cover, table of contents, developer profile, learning objectives and usage instructions, and student activity pages were designed at this stage using Heyzine Flipbook as the digital platform, with embedded Desmos links, animated video explanations, and Google Forms response mechanisms.

Develop

The development phase transformed the draft into a digital e-LKPD through the Heyzine Flipbook platform. Expert validation was conducted by three validators from Universitas Negeri Padang: a language expert (Dr. Abdurrahman, M.Pd.), a media expert (Dr. Nofri Hendri, M.Pd.), and a content expert (Prof. Dr. Ahmad Fauzan, M.Sc.). Validity was calculated using the formula proposed by Akbar (2013).

$$P = (\Sigma x / \Sigma X) \times 100\% \quad (1)$$

where Σx is the total empirical score obtained and ΣX is the maximum possible score. The resulting percentage was interpreted according to the validity category presented in Table 1.

Table 1. Validity category of e-LKPD (Akbar, 2013)

Score	Category	Criteria
81–100	Very Valid	Very good to use
61–80	Valid	Usable after minor revision
41–60	Fairly Valid	Usable after major revision
21–40	Less Valid	Not recommended
0–20	Invalid	Not recommended

Implement

The implementation phase was conducted at SMAN 1 Pariaman, Class X E3 (n = 36 students), during February–March 2026. Implementation followed a one-group pretest-posttest design consisting of a pretest, four learning sessions utilizing the e-LKPD, and a post-test. Both instruments assessed MRS indicators: (1) mathematical observation, (2) pattern recognition and classification, (3) mathematical data interpretation, (4) conjecture formulation and verification, and (5) evidence-based conclusion drawing. Items consisted of context-based essay questions requiring higher-order mathematical thinking. Practicality data were collected via questionnaires administered to one mathematics teacher and all 36 students, analyzed using the same percentage formula (Equation 1). Interpretation followed the practicality categories in Table 2.

Table 2. Practicality category of e-LKPD (Akbar, 2013)

Score	Category	Criteria
81–100	Very Practical	Very good to use
61–80	Practical	Usable after minor revision
41–60	Fairly Practical	Usable after major revision
21–40	Less Practical	Not recommended
0–20	Impractical	Not recommended

Evaluate

Effectiveness was assessed by comparing pretest and posttest MRS scores using the normalized gain (N-Gain) coefficient, calculated as follows (Hake, 1998).

$$g = \frac{\text{Post−test Score} - \text{Pre−test Score}}{\text{Maximum Score} - \text{Pre−test Score}} \quad (2)$$

N-Gain interpretation: high ($g > 0.70$), medium ($0.30 \leq g \leq 0.70$), or low ($g < 0.30$). Distribution normality was assessed using the Kolmogorov-Smirnov test. Given non-normal distribution of pretest scores, the Wilcoxon signed-rank test the appropriate non-parametric test for paired data from a single group measured at two time points, was applied to confirm statistical significance of the pre-post difference. MRS performance was further evaluated using a scoring rubric adapted from Ott (1994) and operationalized by Hartati et al. (2022), employing a four-point scale (1–4) across five MRS indicators.

Result and Discussion

Analysis

The analysis phase confirmed the pedagogical, curricular, and empirical relevance of a Desmos-assisted 5E Inquiry e-LKPD for Linear Programming at SMAN 1 Pariaman. Cognitively, Grade X students are in the formal operational stage (Piaget, 1972), capable of abstract and logical reasoning yet still requiring structured experiences to optimize these abilities. Diagnostic data revealed that 55.5% of students required special numeracy intervention and 33.4% were at the foundational level, indicating particular weaknesses in interpreting contextual problems and applying mathematical reasoning. These findings align with Wulandari et al. (2024), who demonstrated that students with different learning styles exhibit distinct mathematical reasoning profiles requiring differentiated instructional support. From a curriculum perspective, the Merdeka Curriculum (Permendikbudristek No. 12/2024) positions Linear Programming within the Algebra and Functions element, requiring students to model systems of inequalities, analyze feasible regions, and optimize objective functions—activities inherently suited to inquiry-based mathematical reasoning. The existing technology usage in the school was limited to evaluation tools (e.g., Quizziz), with no integration of visualization platforms such as Desmos, despite their recognized potential for supporting mathematical concept construction (Afriana et al., 2016; Ferianto et al., 2023).

Design

The design stage constitutes an essential and strategic phase in the development of a Desmos-assisted *Inquiry Learning* (5E Model) E-LKPD. At this stage, the researcher formulates the initial prototype of the product, including the structure of the E-LKPD, content presentation, learning activities, and assessment instruments. The design process is based on the results of needs analysis, curriculum review, and students' characteristics to ensure that the developed E-LKPD is relevant, engaging, and capable of supporting the achievement of intended competencies effectively.

Figure 2. Media develop: (a) E-LKPD cover page; (b) Table of content page; (c) Developer profile page; (d) CP, TP and instructions for using the e-LKPD page; (e) Student activity page; and (f) Student activity page

Development

After completion of the design phase, the e-LKPD was transformed into a digital format using the Heyzine Flipbook platform, incorporating embedded Desmos links, animated explanatory videos, and Google Forms response mechanisms. Expert validation results are presented in Table 3.

Table 3. Results of the media, language, and material validity test

Measure	Pretest	Posttest	N-Gain
Mean	32	71	0.57
Minimum	17	58	0.38
Maximum	63	96	0.94
N-Gain Category	–	–	Medium
Wilcoxon Asymp. Sig. (2-tailed)	–	–	≤ 0.001

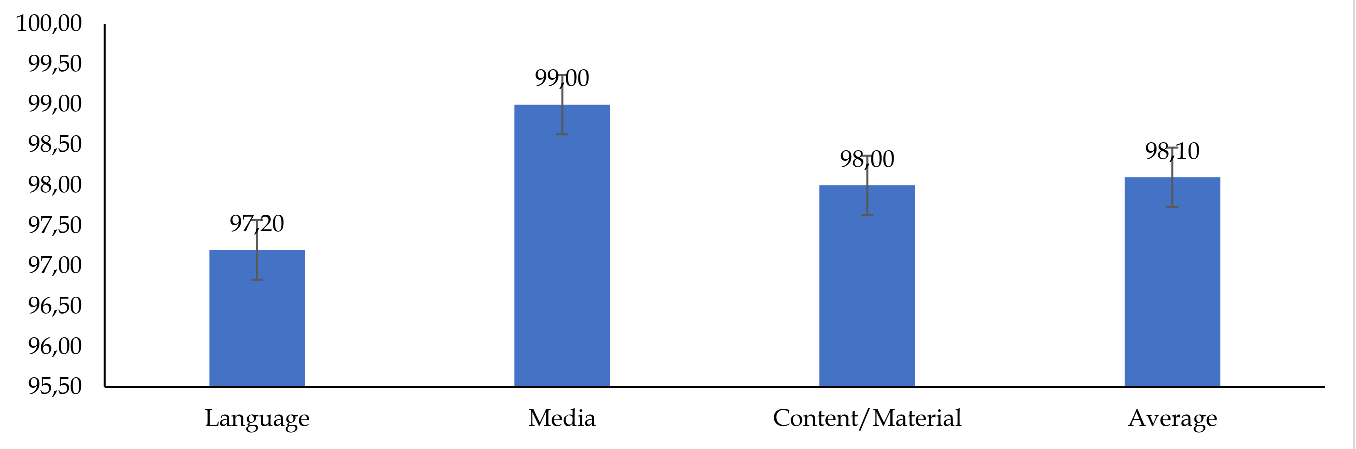

Figure 3. Graph of the results of the media, language and material validity test results

Language validation achieved 97.20%, with readability, language conventions, and communicative clarity aspects reaching 100%. Content validation scored 98.00%, with curriculum alignment, content depth, MRS development, and inquiry learning syntax all achieving 100%. Media validation achieved the highest score at 99.00%, with visual design, layout, and graphic/illustration aspects receiving near-perfect scores. The overall average of 98.07% confirms the e-LKPD meets the "highly valid" criterion, demonstrating high internal consistency among its components (Branch, 2009). These results align with Damayanti et al. (2022), who found that inquiry-based digital worksheets effectively support mathematical reasoning when design elements are consistent with learning theory. The high media score confirms adherence to multimedia learning principles (Mayer, 2014), integrating text, interactive visualizations, and immediate feedback to support knowledge construction. Furthermore, content validity confirms that the MRS indicators embedded in each 5E phase are theoretically grounded and pedagogically appropriate for the Linear Programming topic.

Implementation

Practicality was assessed through response questionnaires administered to one mathematics teacher and 36 students. Results are summarized in Table 4.

Table 4. Practicality Assessment Results

Aspects	Teacher (%)	Category	Student (%)	Category
Content Adequacy	91.4	Very Practical	100	Very Practical
Usability	90	Very Practical	98	Very Practical
Language	80	Practical	–	–
Visual/Display	93	Very Practical	98	Very Practical
Motivation	–	–	93	Very Practical
Interactivity	–	–	96	Very Practical
Overall Average	88.6	Very Practical	97	Very Practical

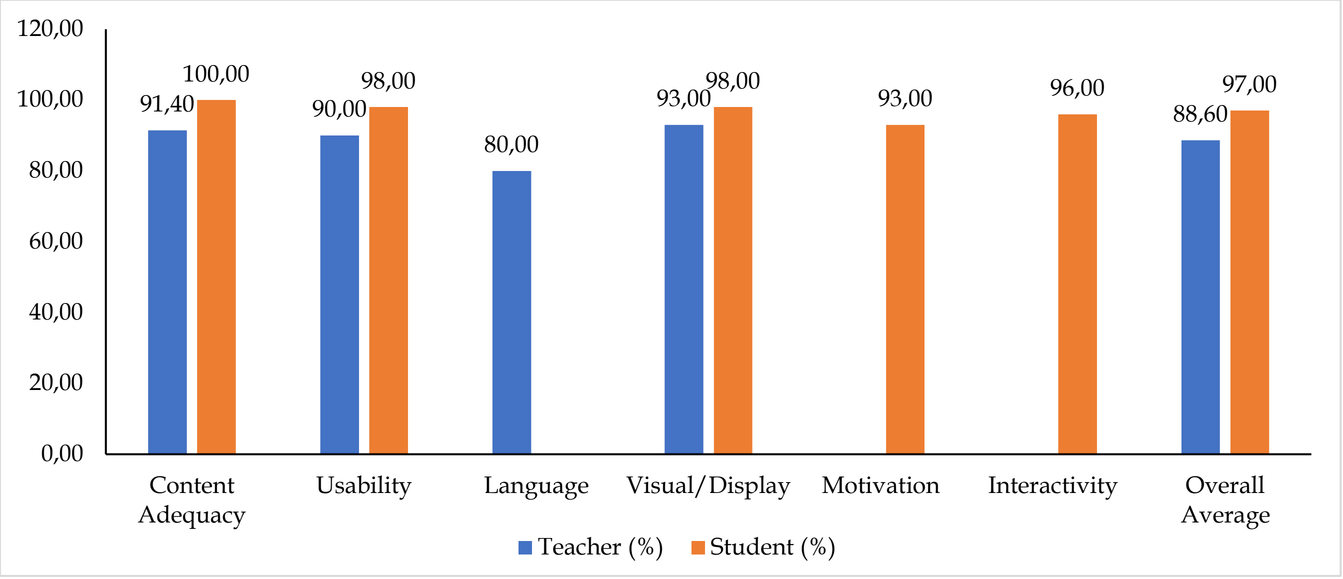

Figure 4. Graph of the results of the teacher and student practicality test

Teacher responses yielded an overall average of 88.60% (very practical), with the highest score on visual/display (93.00%) and the lowest on language/communication (80.00%, practical category), indicating minor revisions are needed in linguistic clarity. Student responses achieved an overall average of 96.36% (very practical), with high scores across all aspects. These findings confirm that the e-LKPD can be used independently with minimal difficulty, consistent with Van den Akker's practicality criterion (Haviz, 2018), a product is practical when users find it both appealing and easy to use. The high motivation score (93.00%) indicates that the e-LKPD creates an engaging and interactive learning environment, aligning with Novitasari et al. (2022), who reported positive student responses to Desmos-based mathematics media. The practical language assessment (80.00%) suggests revisions to instructional language are warranted before final deployment, a finding consistent with Rakhma et al. (2024), who observed that linguistic accessibility of digital media significantly influences student usability perceptions.

Effectiveness of the E-LKPD

Effectiveness was evaluated by comparing pretest and posttest MRS scores. Descriptive statistics and N-Gain results are presented in Table 5.

Table 5. Pretest, posttest, and N-Gain results (n = 36)

Measure	Pre-test	Post-test	N-Gain
Mean	32	71	0.57
Minimum	17	58	0.38
Maximum	63	96	0.94
N-Gain Category			Medium
Mann-Whitney Asymp. Sig.			≤ 0.001

The pretest mean score of 32 reflected low initial MRS mastery, with 44% of students scoring within the 25–32 interval. This baseline corroborates (Aditiyas & Kuswanto, 2024), who reported that students' inquiry-based process skills remain underdeveloped without systematic scaffolding , who found that scientific thinking indicators such as data interpretation and hypothesis formulation require explicit instructional support. Following four learning sessions with the e-LKPD, the posttest mean rose substantially to 71, with 11% of students achieving scores in the 88–93 range and 3% in the 94–99 range.

The Kolmogorov-Smirnov normality test indicated non-normal distribution of pretest scores, necessitating the Wilcoxon signed-rank test the appropriate non-parametric procedure for paired observations from a single group. The test yielded a statistically significant result (Asymp. Sig. 2-tailed ≤ 0.001), confirming that the e-LKPD intervention produced a meaningful improvement in MRS performance. The N-Gain value of 0.57 (medium category, 0.30 ≤ g ≤ 0.70) indicates a practically meaningful level of improvement consistent with Hake (1998) benchmark. Individual N-Gain values ranged from 0.38 to 0.94, reflecting variation attributable to differences in initial mathematical ability, learning style, and engagement with the Desmos activities (Lestari & Muchlis, 2021).

Synergy of 5E Inquiry, Desmos, and Digital Format

The MRS improvement can be attributed to the synergistic integration of three components. First, the 5E Inquiry Learning model provided a systematic framework for mathematical reasoning (Dewi et al., 2017). During the Explore phase, students engaged with Desmos to investigate Linear Programming, directly training observation, data interpretation, and conjecture formulation. During the Elaborate phase, they applied and verified their reasoning in novel contexts, developing critical and adaptive thinking (Koyunlu Ünlü & Dökme, 2022). Second, Desmos enabled dynamic visualization of mathematical relationships, allowing students to manipulate feasible region boundaries and observe objective function optimization in real time. From a constructivist perspective (Piaget, 1972), students constructed understanding of Linear Programming through active exploration rather than passive reception. Vygotsky & Cole (1978) Zone of Proximal Development explains how the e-LKPD's step-by-step instructions and group discussion components provided scaffolding that enabled students to advance beyond their individual competence thresholds. Third, the digital format provided flexibility, accessibility, and immediate feedback, supporting active learning engagement (Ristiani & Hermita, 2022). Jahan et al. (2022) similarly found that digital worksheets enhanced student engagement in mathematics when integrated with structured inquiry (Fakhriyah et al., 2021). These findings collectively demonstrate that mathematical reasoning encompassing observation, classification, data interpretation, conjecture, and conclusion can be effectively developed through the scientific approach mandated by the Independent Curriculum, even within a pure mathematics context (Jihan & Hendriana, 2023; Munika Risa et al., 2021).

Several limitations should be acknowledged. The study involved a single class of 36 students at one school, restricting generalizability. The four-session implementation period may not fully capture sustained effects on MRS development. The reliance on digital devices and stable internet access may have created equity concerns among students. Future studies should address these limitations through larger, multi-school samples (Jumaa & Ismail, 2023).

Evaluation

The evaluation phase combined formative evaluation (conducted throughout design, development, and implementation) and summative evaluation (at the conclusion of implementation). Formative evaluation yielded expert validation scores averaging 98.07% (very valid) and practicality scores of 88.60% (teacher) and 96.36% (student), both in the "very practical" category. Revisions were undertaken based on expert recommendations, particularly regarding material sequencing and linguistic clarity. Summative evaluation confirmed meaningful MRS improvement (N-Gain = 0.57, medium), with significant pre-post differences (Wilcoxon, $p \leq 0.001$). A practical constraint identified during evaluation was that the 60-minute class period was insufficient to complete all e-LKPD activities; accordingly, usage instructions should be revised to recommend a 90-minute session or a structured two-meeting implementation. Overall, the e-LKPD meets the three core quality criteria: valid, practical, and effective (Haviz, 2018), establishing it as a feasible instructional tool for Grade X senior high school mathematics under the Kurikulum Merdeka.

Conclusion

This research successfully developed a valid, practical, and moderately effective e-LKPD based on the 5E Inquiry Learning model assisted by Desmos for enhancing mathematical reasoning skills in senior high school mathematics. Expert validation yielded 98.07% (very valid); practicality assessments yielded 88.60% (teacher) and 96.36% (student), both very practical. Effectiveness analysis yielded an average N-Gain of 0.57 (medium), with the Wilcoxon signed-rank test confirming statistically significant pre-post improvement ($p \leq 0.001$). The integration of the 5E inquiry model with Desmos technology facilitates systematic mathematical reasoning development through dynamic visualization and structured inquiry, supporting the quality mathematics education agenda of SDG 4. Future research should: (1) expand samples to multiple schools to strengthen generalizability; (2) examine extended implementation periods; (3) investigate additional outcome variables including mathematical problem-solving and critical thinking; and (4) explore integration with complementary cognitive technology platforms in diverse mathematical content areas.

Acknowledgments

The researcher would like to thank Prof. Zelhendri Zen, M.Pd., Ph.D as the supervisor, Prof. Dr. Jasrial, M.Pd and Dr. Rayendra, M.Pd., as the examiner lecturer who have provided input and suggestions for my research and I am also grateful to the SMA N 1 Pariaman who has helped me a lot in the research process.

Author Contributions

Conceptualization, R and ZZ; methodology; software, R.; validation, A.F., N.H. and A.; formal analysis, R; investigation, R; resources, R.; data curation, R; writing—original draft preparation, R.; All authors have read and agreed to the published version of the manuscript."

Funding

This research received no external funding.

Conflicts of Interest

The authors declare no conflict of interest.

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